

APPARATUS FOR ILLUSTRATING THE CIRCULATION OF THE LYMPH.

G. S. HOPKINS, D. SC., Cornell University, Ithaca, N. Y.

In describing the lymph circulatory system before a class in anatomy, the writer was enabled to present more clearly and graphically than otherwise would have been possible, the phenomena of the lymph circulation by means of the apparatus described in this paper. But in order to appreciate more fully the excellence of the apparatus as an aid in illustrating the circulation of the lymph, certain points relative to the lymphatic vessels, their function, origin and the course of the lymph through them, should be kept clearly in mind. The function of the lymphatic vessels is to convey the lymph from the tissues back again to the blood from which it originally came; they also serve as one of the main channels for conveying nutritive materials, chiefly fat, from the enteron to the blood.

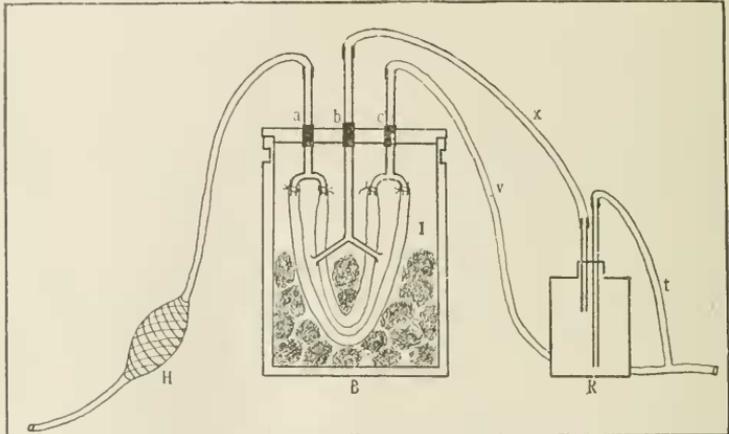
As to the origin of the vessels, there is considerable diversity of opinion, but it seems safe to say that they originate as a network of minute connective tissue spaces which so pervade all living tissues and organs of the body that the individual elements of these tissues and organs are surrounded by and thoroughly bathed in the lymph. From these small interstitial spaces the lymph is gradually collected into larger vessels of which the largest empty into the great receptaculum chyli of the thoracic duct, the latter terminating in the great veins at the base of the neck. The flow of the lymph through the vessels is due to several causes, the chief one of which is believed to be the difference in pressure of the lymph at the two extremities of the lymphatic vessels. At the origin of the vessels the lymph in the interstitial spaces of the connective tissue stands at a higher pressure than in any other part of their course, so that the vessels lead from a region of high pressure—the lymph spaces of the

tissues—to a region of lower pressure, the veins. The high pressure at the origin of the vessels is due, probably, to the fact that the multitude of minute channels through which the lymph must pass before reaching the larger vessels, impedes its flow, but as the lymph is continually transuding through the walls of the blood vessels, from the blood, it accumulates in the minute lymph spaces or radicles, and soon stands at nearly as high a pressure as the blood itself. This high pressure gradually forces the lymph into the larger vessels, where less resistance to its flow is encountered and therefore the pressure necessary to force it along becomes less and less till finally at the terminal end of the thoracic duct the pressure may be even negative. This difference in pressure alone would doubtless cause the lymph to flow in a continuous stream, but in addition to this other causes as the rhythmical contraction of the walls of the lymph vessels; contractions of the muscles including respiratory movements and in some of the lower vertebrates, lymph hearts as well, help maintain the circulation.

With this brief review of the lymphatic system we will pass to the description of the apparatus used for illustrating some of the points above mentioned. No claim to originality is made in connection with the apparatus. It was devised by Dr. T. C. Charles of St. Thomas Hospital, England, and was figured and briefly described by him in the *Journal of Anatomy*, Vol. XXII., p. 435. The only modification made by the writer was to substitute a vessel which opens at the top rather than the bottom, thus somewhat simplifying the construction of the apparatus from the original.

A glance at the figure will show the parts comprising it. The jar, B, should hold from three to four liters, and should have a cover that can be fastened on securely, making the jar air-tight. In the cover were drilled three holes through which the glass tubes a, b, c, were passed. A bit of rubber tubing was placed in each hole in the cover, so that when the tubes were inserted the joints were air-tight. To the lower ends of a and c were tied pieces of prepared intestine, used by butchers as casing for saus-

age. The lower end of *b* opens directly into the general space of the vessel. Attached to *a*, is a rubber tube with a syringe bulb, *H*. From *c* extends another tube, *v*, which is joined at any convenient point by the tube *t*. From *b* the tube *x* extends to the vessel *R*. Some sponges, *S*, may be placed in the vessel *B*, although this is not necessary.



To use the apparatus, the large vessel *B* is filled with water and the rubber tubes connected as shown in the figure. By means of the bulb, *H*, water is forced through the pieces of intestine, *I*, and on through the tube *v*. As the water flows through the pieces of intestine, some of it passes through their thin walls into the space outside, and soon raises the pressure in *B*, so that the liquid is forced through the openings of the tube *b*, and along the tube *x*, into the vessel *R*. As the liquid accumulates in *R* the pressure in this vessel is also raised sufficiently to force the liquid out through the tube *t*. In this apparatus the vessel *B* may be taken to represent the body—the simulation will be more perfect if the vessel be partially filled with sponges to represent the tissues of the body. The intestinal tubes, *I*, represent the blood capillaries of the body. The heart is represented by *H* the arteries by the tube extending from *H*, and the veins by the tube *v*. The tube *b* represents the lymphatic radicles which, as we have already seen, are believed to open directly into the

minute spaces of the body ; these lymph spaces are here represented by the spaces between and in the sponges. The tube x, represents the lymph vessels extending from the lymph radicles to the receptaculum chyli. The vessel R represents the receptaculum chyli. The tube t represents the thoracic duct which extends from the receptaculum to the veins of the neck.

As illustrated by this apparatus the sole cause of the circulation of the lymph is the higher pressure of the lymph at the origin than at the termination of the vessels. In the living body we have already seen that inequality of pressure is thought to be the chief cause of the circulation, but in addition to it, muscular contractions, respiratory movements, and in some of the lower forms, lymph hearts as well, help to keep up the flow.